Horizontal winds, potential vorticity, and stratopause characteristics from a mesospheric and upper stratospheric unified dataset

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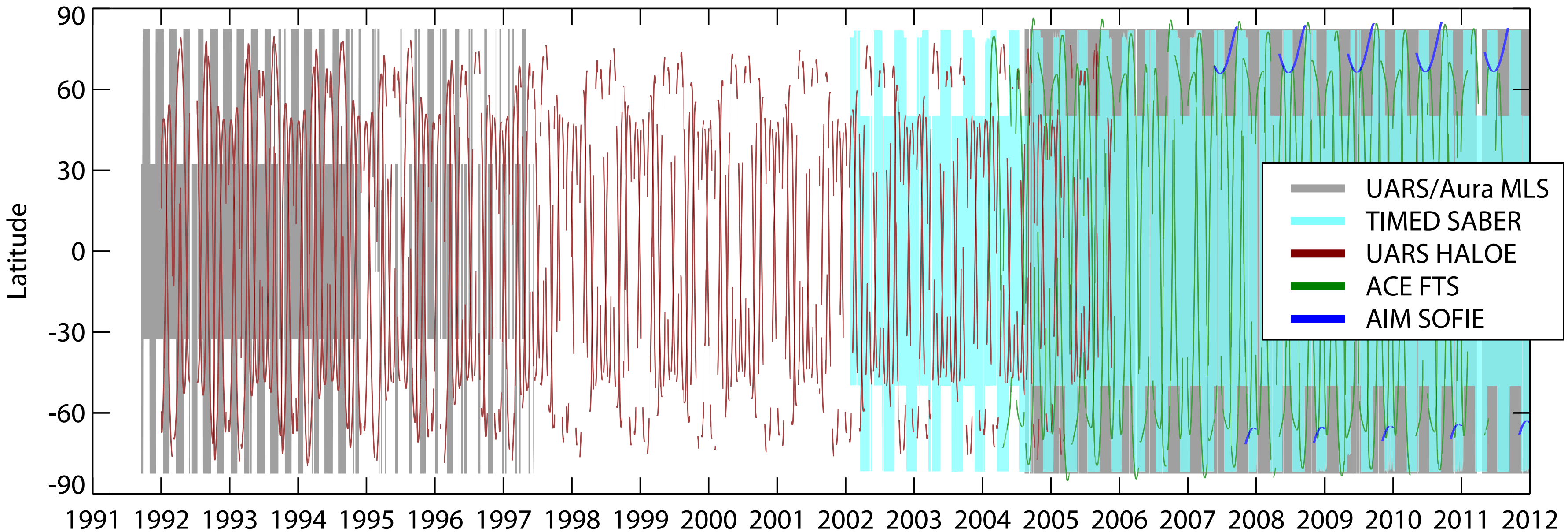

Temporal and latitudinal coverage of observations included in MUSTARD

Mesospheric and Upper Stratospheric Temperature and Related Datasets **(MUSTARD*)** will provide a unified upper stratospheric and mesospheric record based on observations from six satellite instruments (UARS HALOE, UARS MLS, TIMED SABER, ACE-FTS, EOS MLS, and AIM SOFIE) providing a temperature and geopotential height (GPH) record since 1991.

*Supported under the NASA MEaSUREs program.

MUSTARD Objectives

UARS MLS and Aura MLS Level-2 Reprocessing

SALBY reconstruction

Production of Level 3 products

Bias correction

Produce related products
(Winds, PV, and Stratopause Characteristics)

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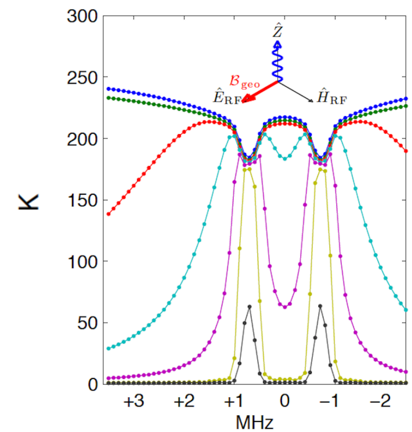
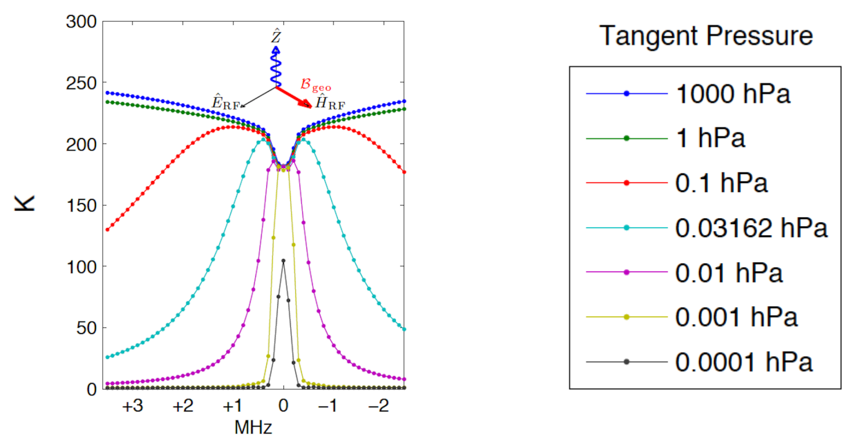


Z: Propagation Direction

B_{geo}: Magnetic field

E_{RF}, H_{RF}: Receiver polarization



Simulated limb radiances covering the Zeeman components of the 118-GHz O2 line. Schwartz (2005) - IEEE TGARS

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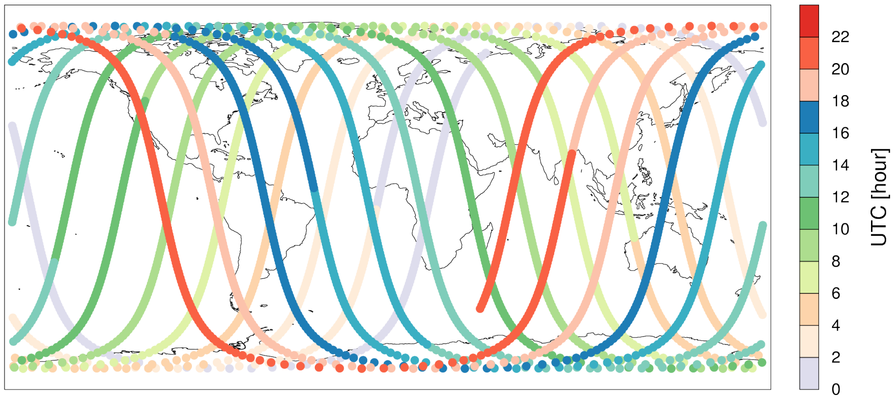

EOS MLS UTC measurements times for January 1st 2005

Ruth Liebermann and her student, Vu Nguyen, lead this effort

MUSTARD Objectives

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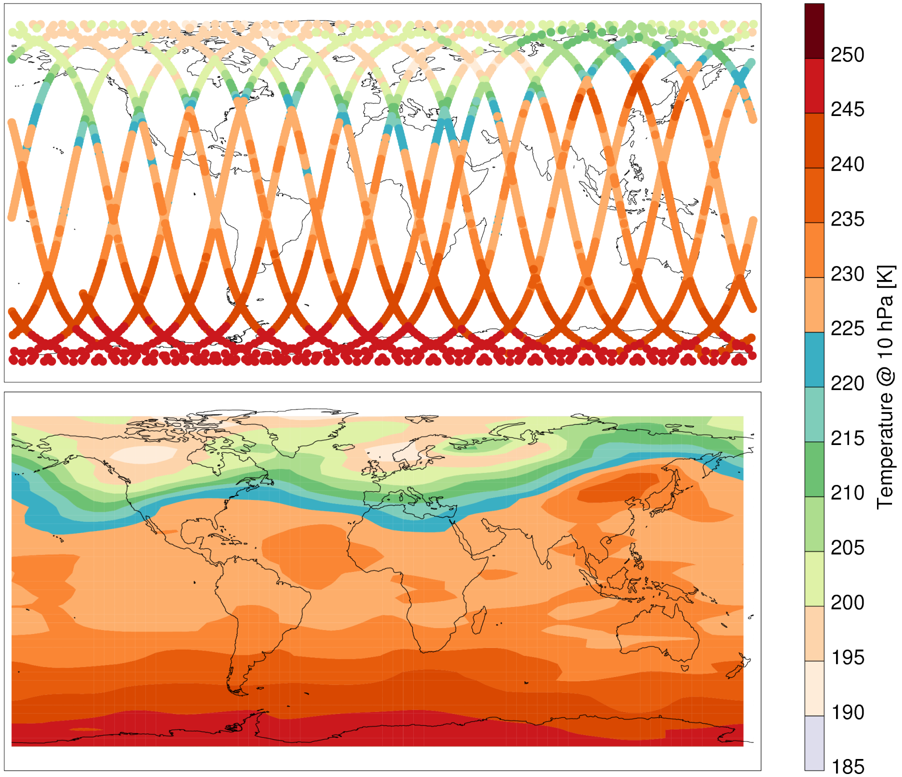


Level 2 (top) and level 3 (bottom) data for January 1st 2005

"Variables mapped on uniform space-time grid scales, ***usually*** *with some completeness and consistency."*

https://science.nasa.gov

MUSTARD Objectives

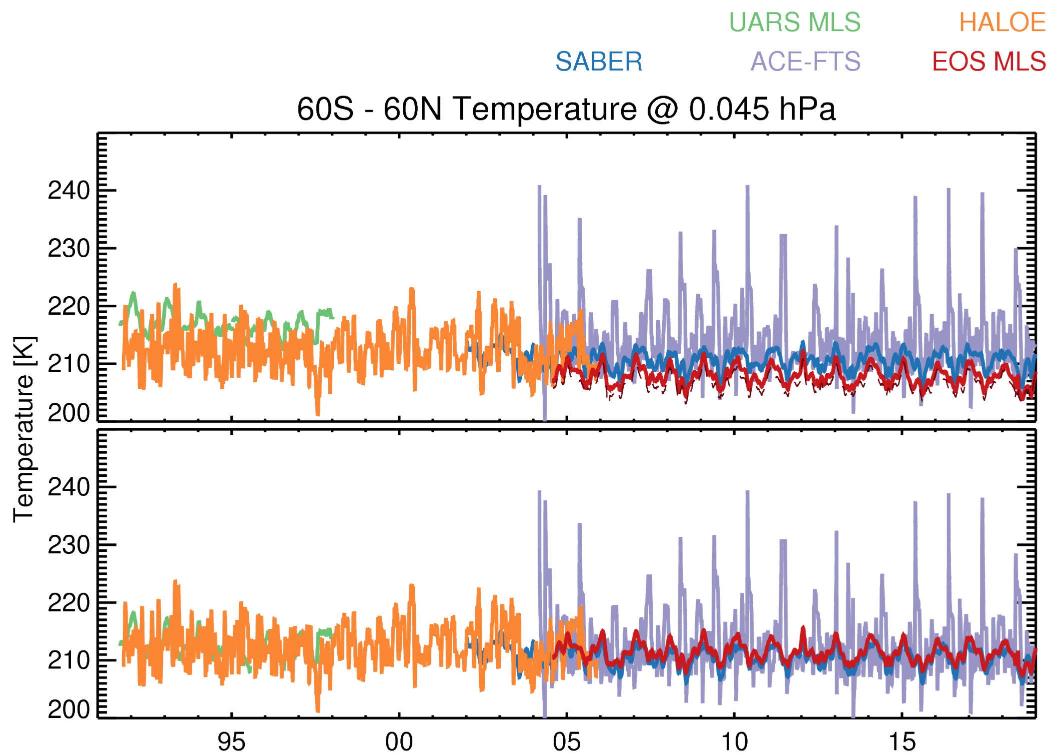
UARS MLS and Aura MLS Level-2 Reprocessing

SALBY reconstruction

Production of Level 3 products

Bias correction (and production of level 3 products again)

Produce related products
(Winds, PV, and Stratopause Characteristics)



(top) Time series of daily mean temperature at 0.045 hPa (approx. 76km) averaged over 60S-60N.
(bottom) Bias corrected time series

MUSTARD Objectives

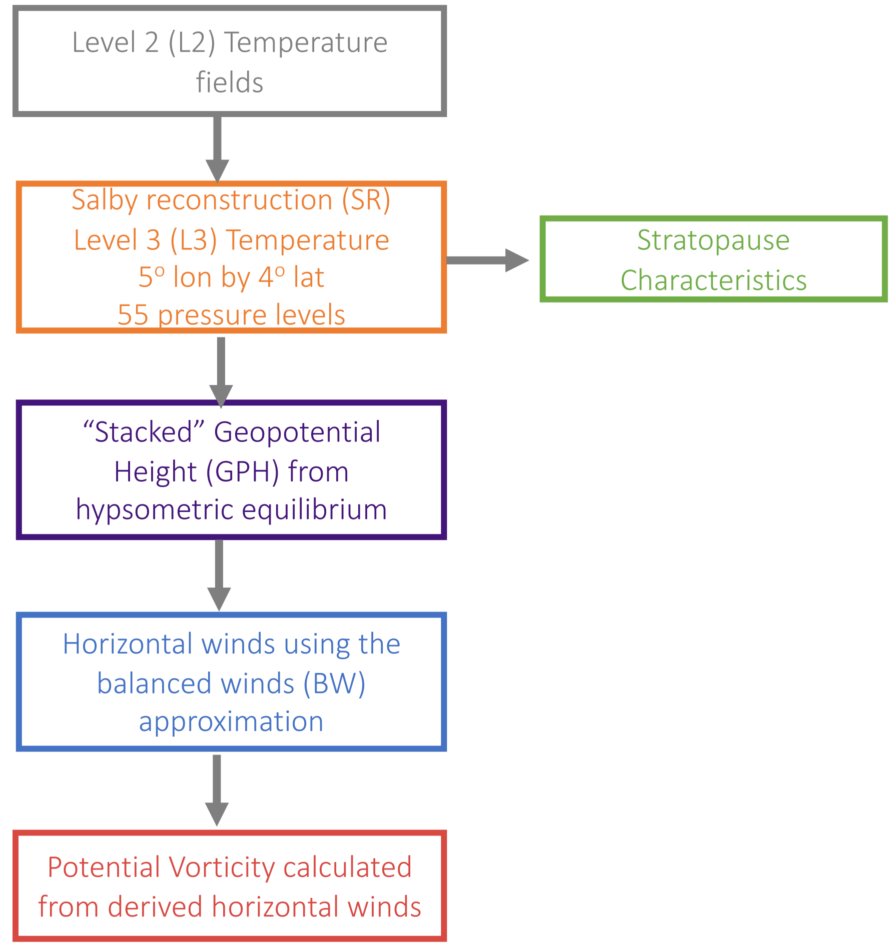
UARS MLS and Aura MLS Level-2 Reprocessing

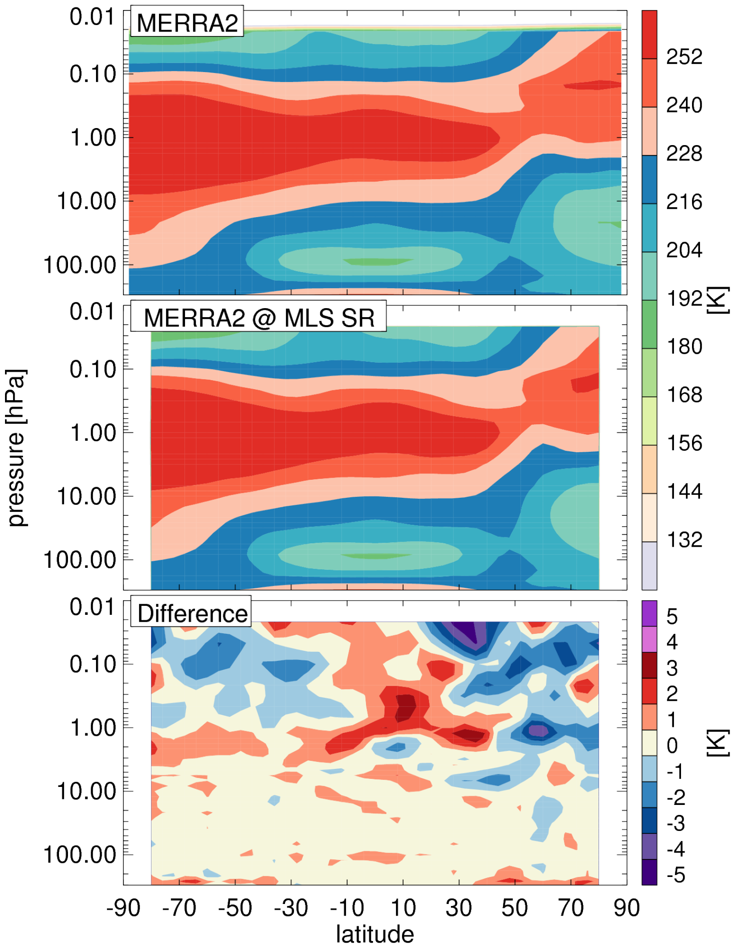
SALBY reconstruction

Production of Level 3 products

Bias correction

Produce related products
(Winds, PV, and Stratopause Characteristics)





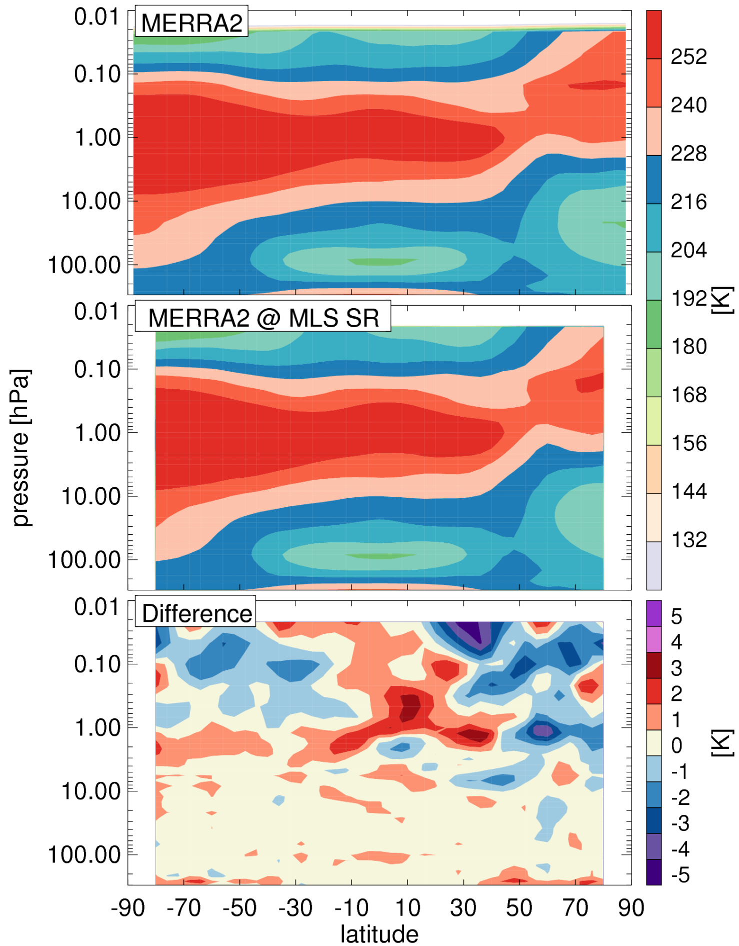
Raw model fields @ 12 UT

MERRA2 sampled at
MLS times and locations

Salby reconstructed (@ 12 UT)

Zonal difference between the MERRA2@ MLS SR and the MERRA2 temperature reanalysis fields for January 1st 2009.

L3 Temperature Record



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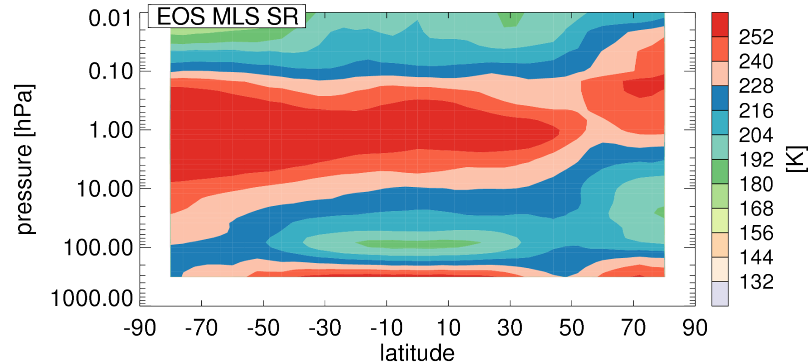
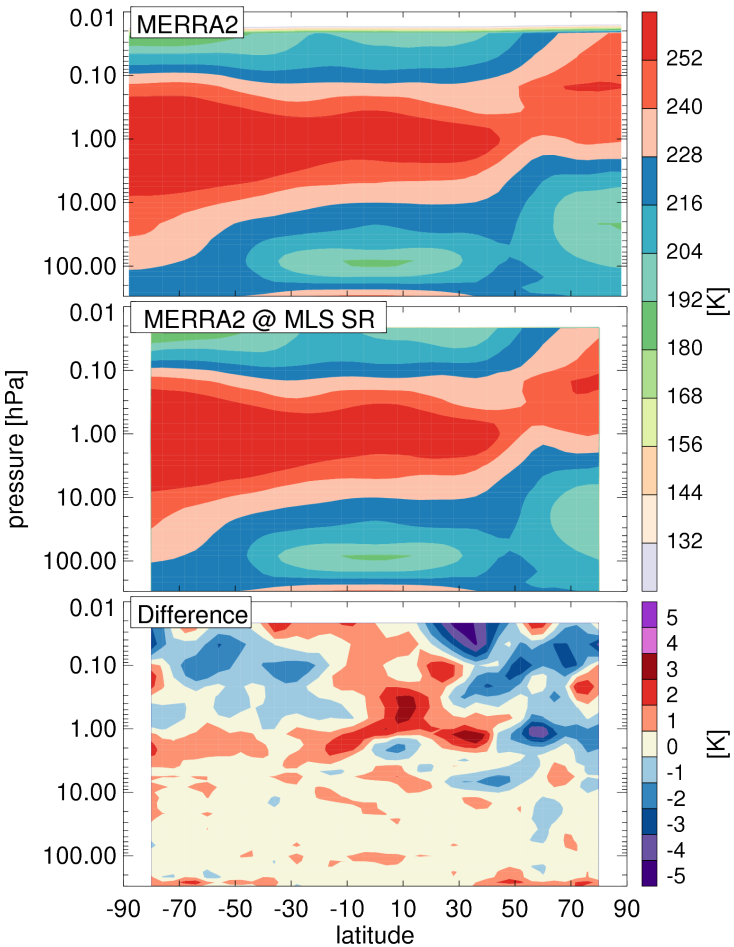


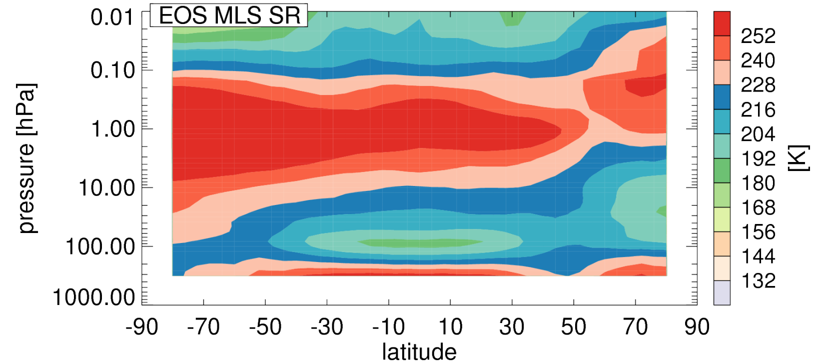
MLS temperature zonal mean for January 1st 2009.

Synoptic reconstruction based on the MLS data

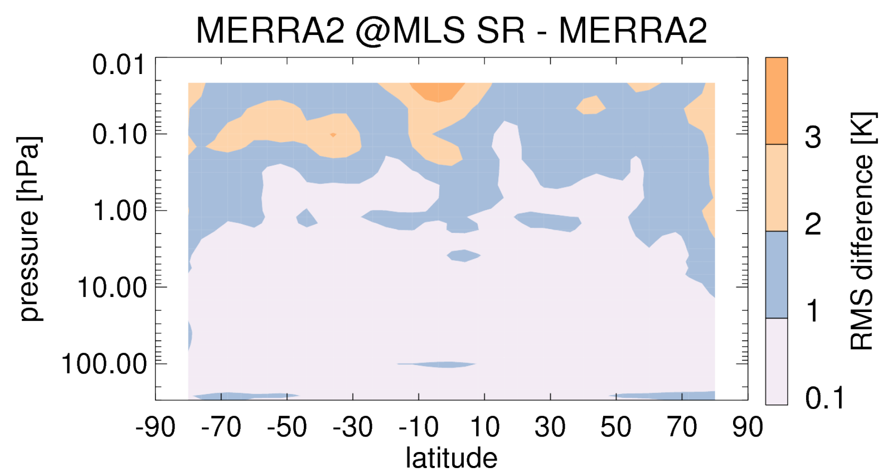
L3 Temperature Record



Zonal difference between the MERRA2@ MLS SR and the MERRA2 temperature reanalysis fields for January 1st 2009.



MLS temperature zonal mean for January 1st 2009.



Zonal RMS 2009 difference between the MERRA2@MLS SR and the MERRA2 temperature reanalysis fields.

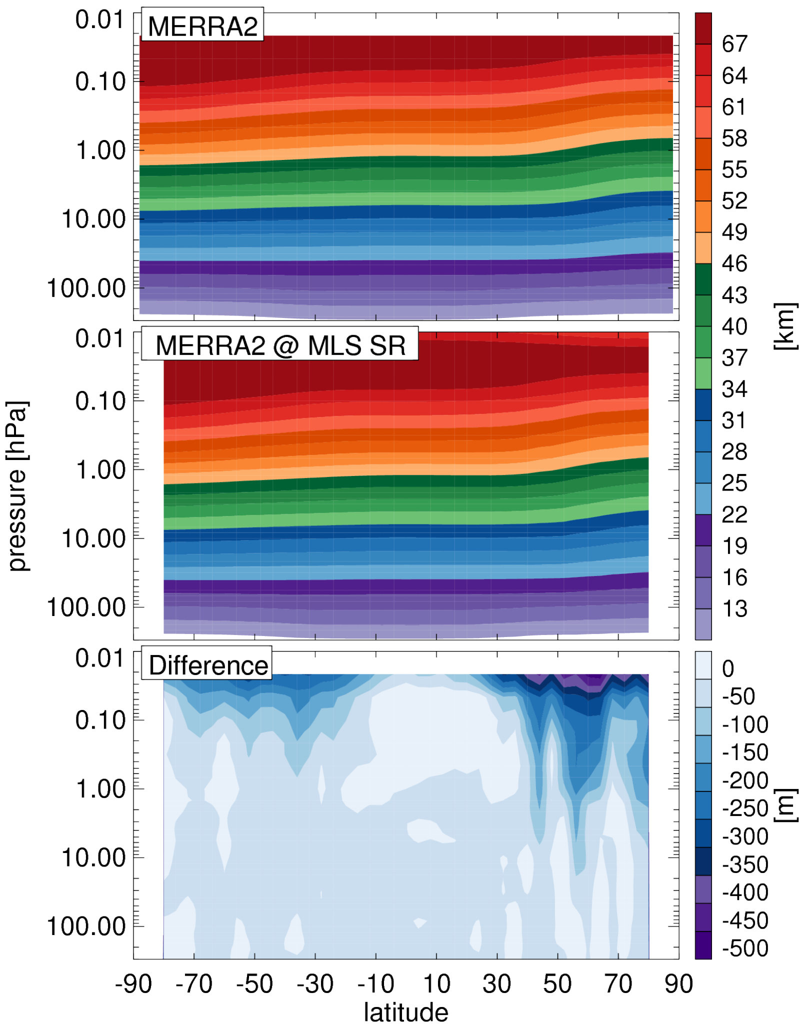
“Stacked” Geopotential Height

Hypsometric equation

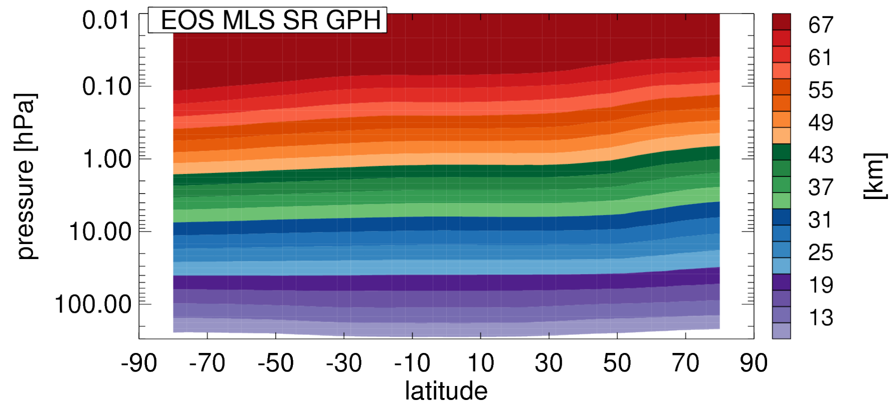
$$z_{i+1} - z_i = \left(\frac{R}{g}\right) \frac{T_i + T_{i+i}}{2} \log\left(\frac{p_i}{p_{i+1}}\right)$$

z: geopotential height
R: gas constant
g: gravity
T: temperature
p: pressure
i: any given level

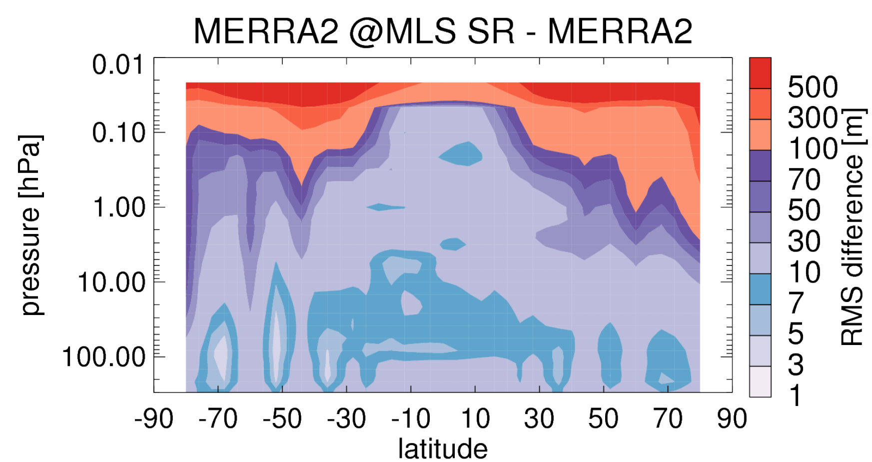
“Stacked” Geopotential Height



Zonal difference between the MERRA2@ MLS SR and the MERRA2 GPH reanalysis fields for January 1st 2009.



MLS GPH zonal mean for January 1st 2009.



Zonal RMS 2009 difference between the MERRA2@ MLS SR and the MERRA2 GPH reanalysis fields.

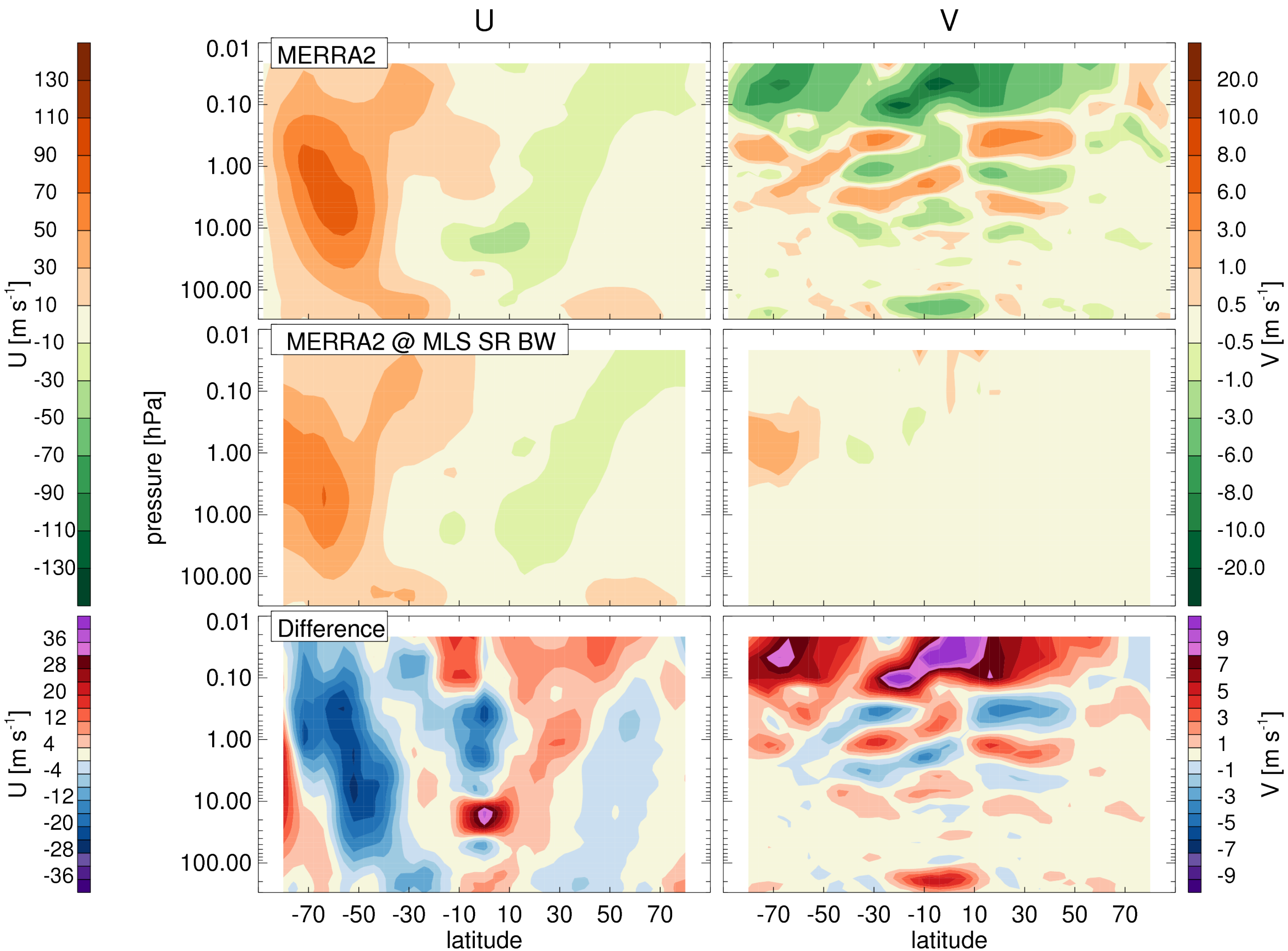
Balance winds approximation

$$2\Omega\sin\phi v = \frac{1}{a\cos\phi}\frac{\partial\Phi}{\partial\lambda} + \left[\frac{u}{a\cos\phi}\frac{\partial u}{\partial\lambda} + \frac{v}{a\cos\phi}\frac{\partial}{\partial\phi}(u\cos\phi)\right]$$

$$2\Omega\sin\phi u = -\frac{1}{a}\frac{\partial\Omega}{\partial\phi} - \left[\frac{u}{a}\frac{\partial v}{\partial\phi} + \frac{u^2}{a}\tan\phi + \frac{u}{a\cos\phi}\frac{\partial v}{\partial\lambda}\right]$$

u: zonal wind
v: meridional wind
a: earth's radius
Φ: geopotential
Ω: earth's rotation rate
ϕ: longitude
λ: latitude

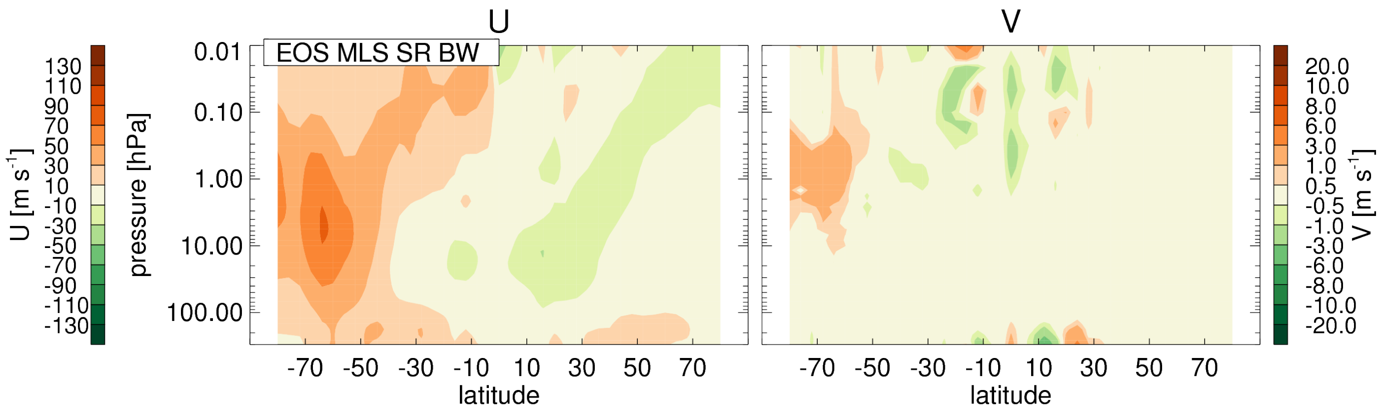
Horizontal Winds



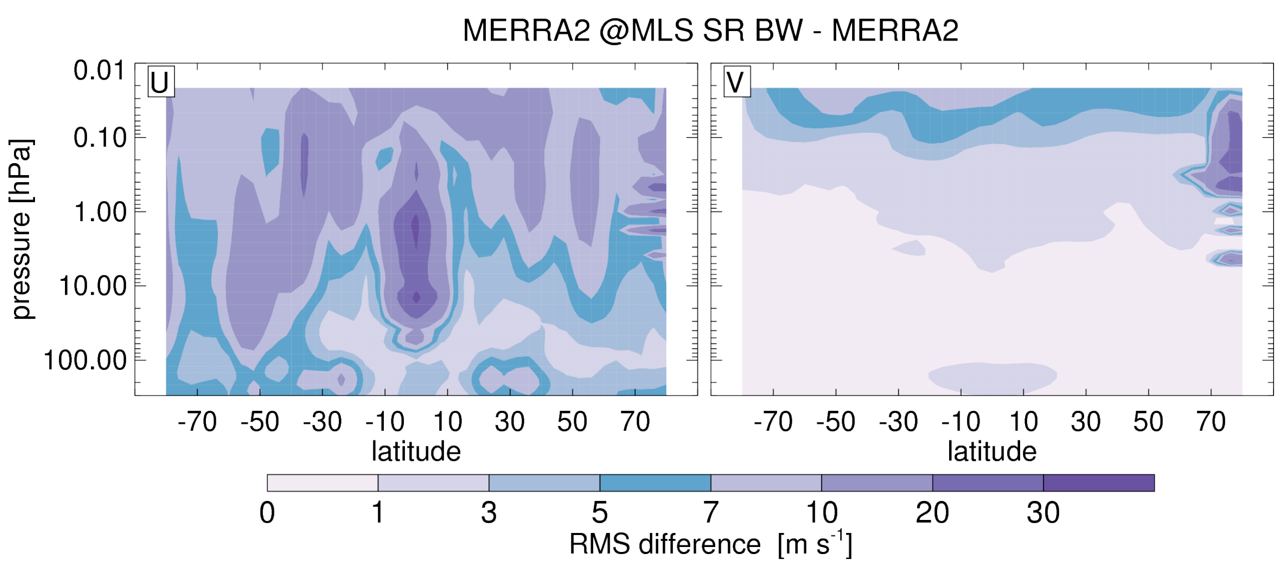
Zonal difference between the MERRA2@ MLS SR and the MERRA2 winds reanalysis fields for January 1st 2009.

Horizontal Winds

MLS zonal and meridional zonal mean for January 1st 2009.



Zonal RMS 2009 difference between the MERRA2@ MLS SR and the MERRA2 zonal and meridional reanalysis fields.



Potential Vorticity

$$\mathrm{PV} = -g\,(\zeta_\theta + f)\,\frac{\partial\theta}{\partial p}$$

PV: potential vorticity

g: gravity

ζ_θ: the component of relative vorticity orthogonal to the θ surface

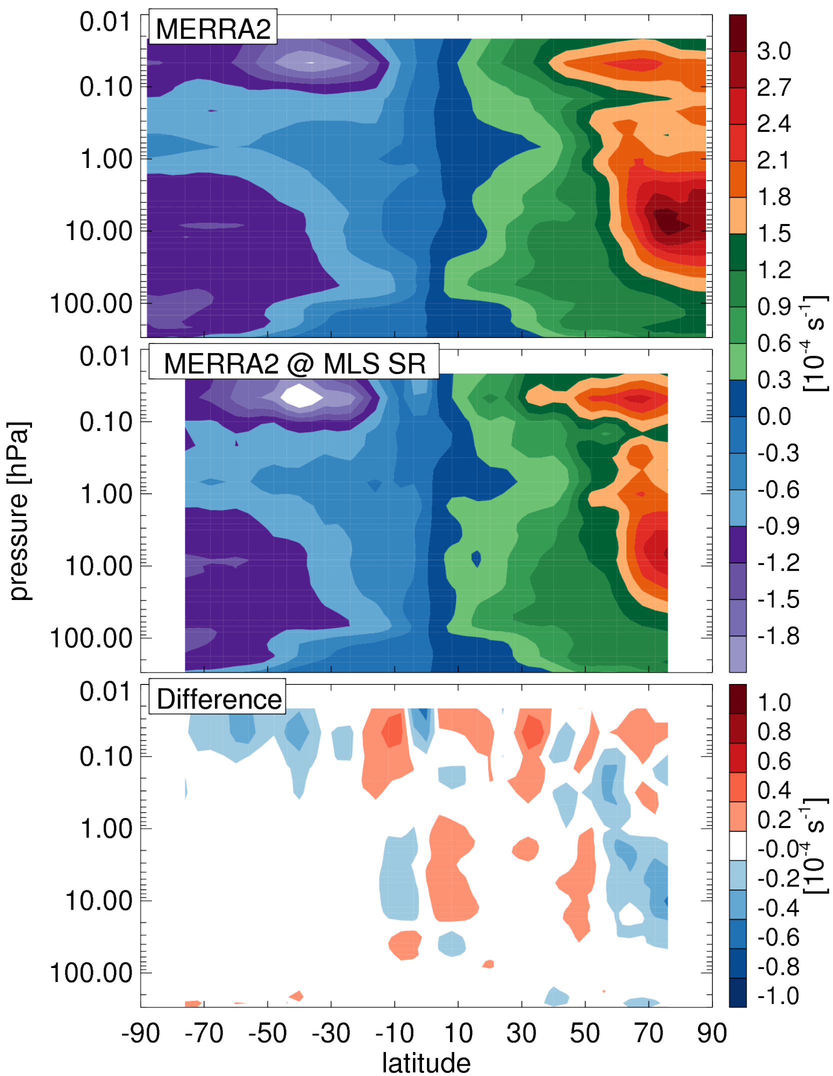
$$\zeta_\theta = \frac{v_\lambda}{a\cos\phi} - \frac{(u\cos\phi)_\phi}{a\cos\phi}$$

f: planetary vorticity

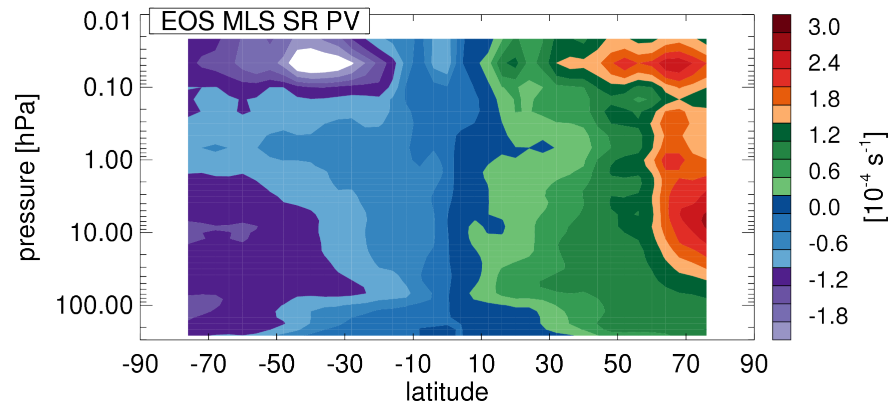
θ: isentropic surface

p: pressure

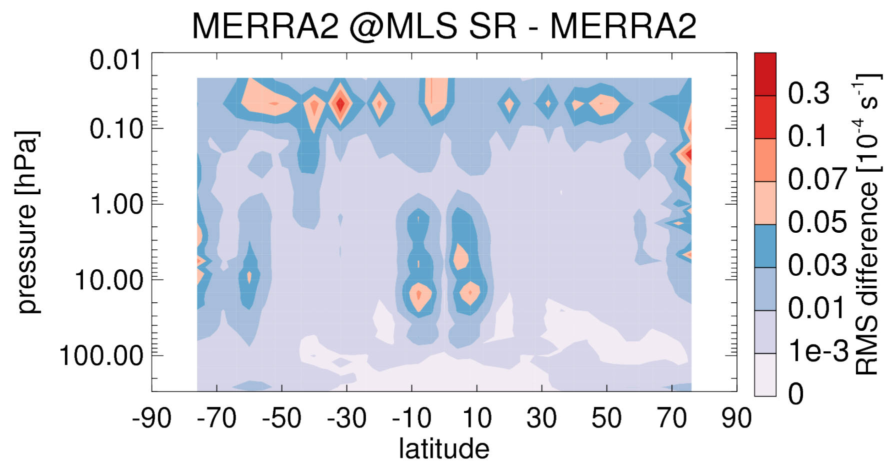
Potential Vorticity



Zonal difference between the SR MERRA2@ MLS and the MERRA2 sPV reanalysis fields for January 1st 2009.



MLS sPV zonal mean for January 1st 2009.



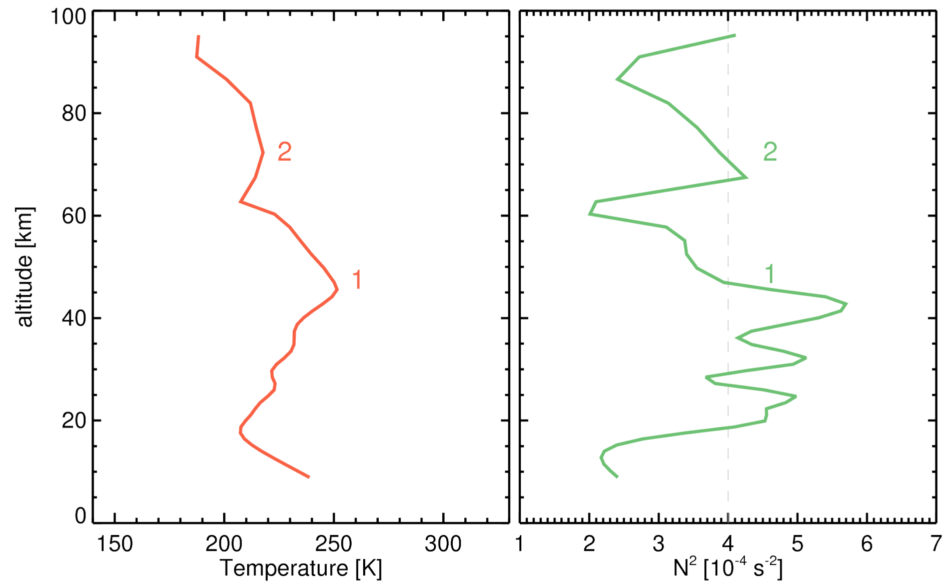
Zonal RMS 2009 difference between the MERRA2@MLS SR and the MERRA2 sPV fields.

Two methods are used to identify stratopauses:

- *Warm point*: local temperature maxima encountered going up from the lower stratosphere

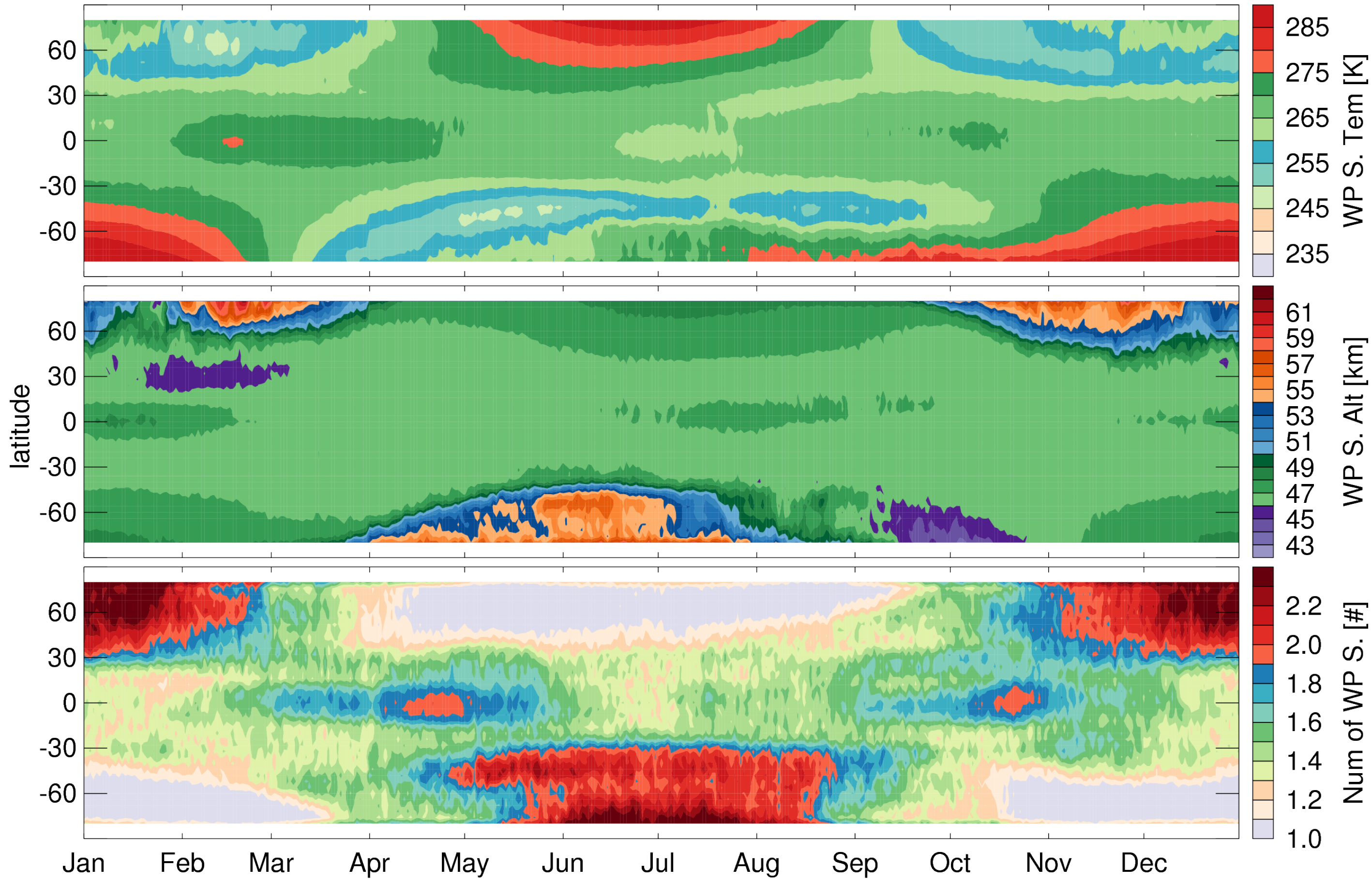
  When more than one stratopause is identified in a given temperature profile, two conditions need to be fulfilled in order for them to be cataloged as individual stratopauses:
  (1) the distance between them needs to be greater than 5km
  (2) the temperature difference between peak and both valleys need to be greater than 5K

- *Static stability*: levels going up from the lower stratosphere where N^2 drops below $4x10^{-4}s^{-2}$



Stratopause characterization examples

Stratopause Characterization



Climatological (2005-2017) latitude-time plot of the warmpoint (WP) stratopause temperature (top), WP altitude (middle) and number of WP stratopauses (bottom) based on the EOS-MLS MUSTARD Salby reconstructed temperature data.

Summary

The Salby reconstructed L3 temperature fields, the “stacked” geopotential height, the horizontal winds, and the potential vorticity (based on the MERRA-2 sampled at the MLS measurement locations) show small RMS differences against the MERRA-2 fields.

Horizontal wind estimates display the largest differences in the tropics, where the balanced wind approximation is not expected to do well [Randel, 1987-JAS].

The MUSTARD derived products will be compared with the MERRA-2 fields taking into account the estimated RMS errors when analyzing their differences.

These datasets should be valuable in evaluation of models and reanalysis fields.

MUSTARD winds and PV could be used to study those fields at the upper stratosphere and mesosphere where reanalysis fields such as MERRA-2 are unreliable or nonexistent.